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Friday, January 17, at 10:00 o'clock  
AMW

110

*George Jan 73*

Date: January 7, 1969

To: Alvin M. Weinberg

Subject: INVESTIGATION OF RELEASE OF APPROXIMATELY TWO Curies  
OF  $^{90}\text{Sr}$  TO MELTON CREEK FROM EXPLORATORY WELL S-220

ChemRisk Document No. 2653

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INVESTIGATION OF RELEASE OF APPROXIMATELY TWO CURIES  
OF <sup>90</sup>Sr TO MELTON CREEK FROM EXPLORATORY WELL S-220

On October 25, 1968, a committee was convened at the request of Alvin M. Weinberg to investigate a release of radioactivity to Melton Branch following the drilling of an exploratory well (S-220) through the several grout sheets formed around the hydraulic fracturing disposal well.

Committee Members

W. H. Jordan, Chairman  
J. H. Gillette  
H. O. Weeren  
T. A. Arehart

During the investigation D. M. Davis and C. R. Guinn of the Applied Health Physics and Safety Section and E. G. Struxness, W. C. McClain, and W. DeLaguna of the Health Physics Waste Disposal Section discussed with the investigators the various factors leading to the release, the stream contamination that resulted, and the effectiveness of hydrofracturing as a method for disposal of intermediate level waste.

The operators provided descriptive material which, along with items brought out in the investigation, resulted in the following resume.

Factors Leading to Release and Stream Contamination

Well S-220 was drilled for two purposes: (1) to obtain samples of the several grout sheets, both experimental and operational, which had been formed around the hydraulic fracturing disposal well; and (2) to add another gamma-ray logging well to the six which are now in use for determining the location of the injections. As such it is part of a continuing program to obtain the facilities for more closely determining the extent of the injections.

The "pilot hole" for this well was drilled and cased to a depth of 600 feet in the spring of 1967. Deepening of the well by core drilling through the zone of interest began about June 1, 1968. By June 7, the well had reached a depth of 806 feet, when drilling was stopped briefly in order to get the gamma-ray log of the natural radioactivity of the beds penetrated to that depth. The log obtained showed only natural activity.

On June 10, when the drillers arrived at the well, they noted the very slow flow of water from the well. They had been asked to look for this. The water comes from the shale which has been slightly compressed by the uplift resulting from the injection of the underlying grout sheets. This flow is very small and, if given several months, would total only a few hundred gallons. The water contained no activity. The well at this time was 815 feet deep.

The first radioactive grout sheet was penetrated on June 13 at a depth of 864.1 feet. Some activity was noted in the drilling water within not more than 2 or 3 hours after penetrating the grout sheet. During drilling some 10 gallons per minute of clear water is pumped down the well to cool the bit and bring up cuttings. As per standing instructions, the Applied Health Physics surveyor was called; and he instructed the drillers to "dress out" for work in a contaminated area. Some provision was made to confine the drilling water coming from the well into a small channel draining toward Melton Creek, which is only 20 feet from the well. Consideration was given to digging a small pit to let the drill cuttings settle out as most of the activity at this time appeared to be contained in the powdered cement-clay grout, but the depth to the water table near the creek is less than 3 feet. Also, the well is so near the creek that the only obvious place for a pit appeared to be very near the drill where there would be a possibility of the drillers stumbling into it.

Drilling of the well was completed on July 5, 1968. Contamination on the ground along the path followed by the drill water read about 50 mr per hour on contact, but the radiation field where the drillers were working was much lower. Contamination was noted in the drill water for a few minutes each morning, about half an hour after starting to drill; it takes about a half-hour for drill water from the bottom of the hole to reach the surface. Later during the day no contamination could be noted in the water.

At some time in late June or early July several loads of crushed rock were used to cover the dirt in the work area, and this appeared to have eliminated most of the contamination problem.

On July 23, 25, and 26, the completed well was surveyed for deviation and direction from the vertical, at which time it was noted that the well was still flowing very slowly, a few gallons per hour at most; and the water appeared to be only slightly contaminated.

Up to this time nothing unusual had happened. The operators were accustomed to drilling through active grout sheets and recovering small amounts of activity, but these were only significant in that they might contaminate the workmen or logging equipment.

About the middle of August the operators were informed that the water sampling station on Melton Creek, about 300 feet downstream from well S-220, had picked up unusual amounts of activity. The well was checked on August 16 and was found to be flowing very slowly - a few drops a minute. A sample of the water was analyzed for radioactivity and was very much more active than anything seen previously (Table 1).

It is now obvious that the fracture intersected at 864 feet, which contained the grout from operational waste injection ILW-4, made in April, 1968, and also about 35,000 gallons of water from a water-injection test in December, 1967, had leaked enough to displace the 500 gallons of drill water overlying it in the well and was now flowing out. An estimated 1000 to 1500 gallons of water leaked out of this fracture. In retrospect, it was a poor idea to inject 100,000 gallons of highly radioactive grout into a fracture already containing 35,000 gallons of water, but the resulting escape of only two curies of activity show that the consequences were relatively small.

About October 1 the drill crew returned to the well to ream the bottom part of the well and set casing to the bottom. Analysis of the water showed that the nearly stagnant water in the well contained about one curie of strontium. This water would be flushed out by the reaming. The water was controlled during the reaming operation by directing the well overflow to a lined trench. Whenever the trench was full, the contaminated water was pumped into a tank truck and disposed of into the former waste disposal pit No. 4, into which the contaminated sludge from the process waste treatment plant is discharged.

There was no indication at the well that important quantities of activity were reaching the stream until the analysis of the water sample from the well on August 16. By this time the flow of the well had nearly stopped. Data from the monitoring stations on Melton Creek, just below the well and at the dam on White Oak Lake, showed increased escape of strontium somewhat earlier. (See Tables 2, 3, and 4.) The contamination of Melton Creek with two curies of activity was not predictable on the basis of earlier

drilling, during which only very small amounts of activity were released. Being forewarned, all necessary precautions will be taken in any further drilling.

#### Effectiveness of Hydrofracturing

In disposal by hydraulic fracturing, the principal containment is provided by the several hundred feet of overlying essentially impermeable shale, which, for some 800,000,000 years, has protected the underlying red shale into which the injections are made. The red shale contains dispersed sodium chloride, small amounts of brine in the very fine pores of the shale, which comprise 1% of the volume of the shale, and small amounts of nitrogen and methane gas under a pressure locally as high as 30 psi. If there were any natural movement of water through the shale, either laterally or vertically, the salt would have been leached out. If there were any measurable vertical permeability to the shale, the gas would also have escaped. In drilling a 3-inch hole vertically through the shale, a passageway of essentially infinite permeability was artificially provided. This is far worse than any "maximum credible accident," because the calculated point of failure is the point at which a vertical fracture would form locally in the limited region of maximum increase or vertical stress. Once the vertical fracture had moved a short distance up out of this region, it would turn and become horizontal. There is no logical way in which a vertical fracture could form leading from the grout sheets all the way up to the surface.

The second important barrier to the escape of activity from the deep fractures is the ion-exchange capacity of the shale, the same capacity for containment that was demonstrated by the waste pit system. Any natural pathway leading from the fractures to the surface (if one could form) would be itself in the nature of a fracture and, as the shale cannot break cleanly normal to the bedding, the fracture would lead through broken or powdered shale. A natural fracture would expose any escaping liquid to a large surface area of shale with consequent decontamination by ion exchange. Well S-220, as a cylinder, not only placed a very limited surface area in contact with the solution, but the larger part of this well was already cased with steel, and offered no contact with the shale at all. The well, therefore, not only breached completely the principal containment but also rendered inoperative the secondary containment.

The third line of containment is artificial and resides in the physical and chemical properties of the mix. Ideally, the mix should immobilize on hardening all the liquid in the waste, and

should incorporate all the activity either into the crystal structure of the newly formed minerals or should bind it up by ion exchange. In practice, it has not been possible to achieve 100% of these goals.

Fluid containment in the mix is dependent, at least in part, on preventing phase separation. Attapulgitic clay is added to thicken the liquid and prevent the cement and fly ash from settling out. However, the physical properties of the mix depend on the amount of shear to which the mix is subjected; the more rapidly and thoroughly it is stirred the less the solids tend to settle. If there is little shear in the mixing, the colloidal attapulgitic clay is not sufficiently dispersed to prevent entirely all phase separation. The amount of shear provided by the mixing and pumping in the disposal plant has not been measured and, therefore, it has not been possible to duplicate it in the laboratory. It is believed there is but little phase separation with the mix now being used for the current waste disposal operations, but it cannot be evaluated quantitatively.

A related problem is what may be called "filter pressing." After the waste mixture has been injected, but before it has set up, some liquid is squeezed out into the shale. Even though the shale is very nearly impermeable, pressures of 500 to 1000 psi are maintained in the fracture for some time; and this, in combination with the very large surface area of the fracture, results in some fluid loss to the shale. This is not in itself harmful, for once in the shale the fluid cannot move far. This fluid at first is under considerable pressure, and observations show that a year or two is required for the pressures to slowly dissipate. The drop in pressure in the fracture, as measured at the wellhead following the waste injection of April, 1968, is shown in Figure 1. The period covered is about 2 months, by which time the pressure had dropped from over 2000 psi to about 200 psi. About 2 months later, when well S-220 intersected the fracture, the pressure was of the order of 100 or 150 psi, and yet only about 1500 gallons of liquid came out of the fracture. If the well had been drilled a year or two later, the amount of "bleed back" would have been negligible. This means that, although the grout on setting does not contain and immobilize all of the water, a year or two later the substantial pressures, which are required to move even small volumes of liquid out of the cement-filled fracture or out of the adjacent shale, have vanished and the liquid is effectively locked in place. It is believed that no liquid escaped from the fractures formed prior to April, 1968, when they were penetrated by well S-220.

Both phase separation and the loss of liquid to the wall rock by filter pressing could be reduced by using a faster setting mix. The present mix, varied as indicated by laboratory tests on the particular waste to be injected, requires about 2 days to set. Further work on the problem of mix development would be desirable, although the present mix is performing at least as well as predicted.

Another property of the mix is to hold the radioactive fission products either by incorporating them into the newly formed minerals or by adsorbing them onto the surface of the solid materials. The composition of the water that leaked out of the uppermost grout seam penetrated by well S-220 is shown in Table 1. The concentration of strontium is less than 5% of the concentration of strontium in the waste injected, and cesium shows less than 0.5% of the concentration in the waste. The 3 curies of strontium that were present in this water are less than 0.1% of the strontium contained in injection ILW-4. The total amount of activity that had been injected, and that was contained in the six main grout sheets intersected by the well, was over 150,000 curies. It is probable, although it cannot be proved, that all of the activity that appeared in the water from well S-220 came from the last waste injection, ILW-4, made in April, 1968, only 3 to 4 months prior to the drilling of the well.

A factor that is difficult to evaluate, but which may have adversely affected the retainment of both liquid and activity in the fracture holding ILW-4, was the water injection test (previously mentioned) made in December, 1967. In the course of this test some 50,000 gallons of water were injected into a new fracture, opened up for the purposes of the test. This water was left in the fracture for two months, at which time the pressure had dropped to about 200 psig. The well head was then opened and something less than 15,000 gallons was backflowed out of the injection well. Injection ILW-4 was made into this same fracture, directly on top of some 35,000 gallons already held in the shale. Nothing of this sort would normally be done in a disposal operation; but, as expected, the waste was very largely immobilized and only small quantities of activity were brought to the surface by the water in well S-220. The quantities would probably have been less had the 35,000 gallons of water not been there, and certainly would have been less had well S-220 been drilled a year or two later than it was.

In order to obviate the effect of the 35,000 gallons of water, succeeding injections will be made into new fractures above the ILW-4 injection.

### Committee Conclusions and Recommendations

The Committee addressed itself to two questions:

1. Did the incident reflect on the safety of the present operation of waste disposal in Melton Valley by hydrofracture?
2. Is the incident significant from the standpoint of feasibility of disposal by hydrofracturing at other locations?

1. The committee is not worried about the safety of the present operation in Melton Valley. Compared to the previous disposal by dumping the intermediate level waste into open pits or trenches, it is at least two orders of magnitude less hazardous. The release of approximately two curies of  $^{90}\text{Sr}$  did not significantly add to the contamination of White Oak Creek or the Clinch River. The explanation that the excessive "bleed back" of contaminated water was caused by the residual 35,000 gallons of water in the fracture prior to the ILW-4 injection is reasonable. The fact that so little activity escaped when the fracture was directly connected to the surface could be considered a distinct plus for the method. Even so, the experimenters will certainly be more careful in the future.
2. The committee is of the opinion that the incident does have implications concerning the future of the hydrofracturing. The fact that the contaminated bleed back was unexpected points up the need for further research. There is much that is not understood about the hydrofracture mechanism, particularly the circumstances under which horizontal fractures can be guaranteed. Only the roughest estimate can be made of the capacity of a well to receive wastes or even the mechanism of failure if a well is overtaxed, a most important consideration when economics and safety are involved. More research is needed on the constituents of the mix that is pumped into the well. Although laboratory tests have been made on the setting characteristics of the mix, it is not possible to duplicate the conditions at the bottom of the well. Consequently, it is difficult to predict how much phase separation occurs and hence how much radioactivity in the form of a solution is available to move into the interstices of the formation or along any crack that might open up. This problem is of more concern than the small amount of water that is injected prior to injecting the mix.

The hydrofracturing facility was built as an experiment and was never adequately engineered as a production facility. Enough



has been learned that a much better design could now be made. The present operation is meant to get the waste underground at a minimum of expense. If the objective also included learning as much about the operation as possible and to make it safe under any conceivable circumstances, there would have to be a considerable number of improvements made - not only better equipment but also more rigorous quality control.

The experience in disposing of real wastes on a routine basis has been very valuable. However, it is not likely that this experience will be used in furthering the technology of underground disposal since the research effort was prematurely cancelled. The incident that this committee was formed to investigate is only a symptom of the inadequate state-of-the-art of disposal of waste by hydrofracture.

*for* F. R. Bruce  
W. H. Jordan, Chairman

J. H. Gillette  
J. H. Gillette

T. A. Arehart  
T. A. Arehart, Secretary

H. O. Weeren  
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Table 1. Water Samples from Well S220

August 16, 1968

|                        |                                  |
|------------------------|----------------------------------|
| <sup>90</sup> Sr-----  | 9.2 x 10 <sup>5</sup> dis/min/ml |
| <sup>106</sup> Ru----- | 1.6 x 10 <sup>4</sup> dis/min/ml |
| <sup>137</sup> Cs----- | 3.4 x 10 <sup>4</sup> dis/min/ml |
| <sup>60</sup> Co-----  | 1.6 x 10 <sup>3</sup> dis/min/ml |

October 14, 1968

|                        |                                   |
|------------------------|-----------------------------------|
| <sup>90</sup> Sr-----  | 7.96 x 10 <sup>5</sup> dis/min/ml |
| <sup>106</sup> Ru----- | 9.96 x 10 <sup>3</sup> dis/min/ml |
| <sup>137</sup> Cs----- | 4.32 x 10 <sup>4</sup> dis/min/ml |
| <sup>60</sup> Co-----  | 1.82 x 10 <sup>3</sup> dis/min/ml |

Table. 2. Melton Creek Monitoring Station

|       |                |      |                                 |
|-------|----------------|------|---------------------------------|
| May   | Gross $\beta$  | 1.0  | counts/min/ml                   |
|       | Gross $\gamma$ | 4.0  | counts/min/ml                   |
|       | Sr             | 0.5  | dis/min/ml; total, 0.05 curie   |
|       | Ru             | 0.03 | dis/min/ml; total, < 0.01 curie |
|       | Cs             | 0.01 | dis/min/ml; total, < 0.01 curie |
| June* | Gross $\beta$  | 5.0  | counts/min/ml                   |
|       | Gross $\gamma$ | 3.7  | counts/min/ml                   |
|       | Sr             | 6.6  | dis/min/ml; total, 0.72 curie   |
|       | Ru             | 0.13 | dis/min/ml; total, < 0.01 curie |
|       | Cs             | 0.11 | dis/min/ml; total, < 0.01 curie |
| July  | Gross $\beta$  | 12.0 | counts/min/ml                   |
|       | Gross $\gamma$ | 4.0  | counts/min/ml                   |
|       | Sr             | 18.7 | dis/min/ml; total, 1.35 curies  |
|       | Ru             | 0.37 | dis/min/ml; total, 0.03 curie   |
|       | Cs             | 0.16 | dis/min/ml; total, 0.12 curie   |
| Aug.  | Gross $\beta$  | 2.5  | counts/min/ml                   |
|       | Gross $\gamma$ | 34.0 | counts/min/ml                   |
|       | Sr             | 2.1  | dis/min/ml; total, 0.13 curie   |
|       | Ru             | 0.2  | dis/min/ml                      |
|       | Cs             | 0.06 | dis/min/ml                      |
| Sept. | Gross $\beta$  | 4.0  | counts/min/ml                   |
|       | Gross $\gamma$ | 1.0  | counts/min/ml                   |
|       | Sr             | 0.66 | dis/min/ml                      |
|       | Ru             | 0.37 | dis/min/ml                      |
|       | Cs             | 0.06 | dis/min/ml                      |

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\*Well S220 penetrated the fracture holding waste injection ILW-4 on June 13.

Table 3. Strontium<sup>a</sup> (total) in White Oak Lake Effluent--1968

| Week Ending<br>Date | Conc. over<br>White Oak Dam<br>(10 <sup>-6</sup> $\mu$ c/ml) | Total Discharged<br>for Week<br>(curies) | Calculated Conc.<br>in Clinch River<br>(10 <sup>-8</sup> $\mu$ c/ml) | % MPC <sub>w</sub> <sup>b</sup><br>in River |
|---------------------|--|--|--|---|
| 1-7-68              | 0.29   | 0.16                                     | 0.04   | 0.13  |
| 1-14-68             | 0.29   | 0.23                                     | 0.10   | 0.33  |
| 1-21-68             | 0.34   | 0.07                                     | 0.05   | 0.17  |
| 1-28-68             | 0.44   | 0.08                                     | 0.06   | 0.20  |
| 2-4-68              | 0.41   | 0.07                                     | 0.06   | 0.20  |
| 2-11-68             | 0.35   | 0.05                                     | 0.06   | 0.20  |
| 2-18-68             | 0.36   | 0.04                                     | 0.05   | 0.17  |
| 2-25-68             | 0.37   | 0.04                                     | 0.05   | 0.17  |
| 3-3-68              | 0.26   | 0.03                                     | 0.06   | 0.20  |
| 3-10-68             | 0.52   | 0.06                                     | 0.17   | 0.60  |
| 3-17-68             | 0.32   | 0.17                                     | 0.43   | 1.4   |
| 3-24-68             | 0.30   | 0.09                                     | 0.68   | 2.3   |
| 3-31-68             | 0.29   | 0.06                                     | 0.47   | 1.6   |
| 4-7-68              | 0.27   | 0.10                                     | 0.47   | 1.6   |
| 4-14-68             | 0.27   | 0.07                                     | 1.4  | 4.7   |
| 4-21-68             | 0.29   | 0.06                                     | 0.33   | 1.1   |
| 4-28-68             | 0.44   | 0.06                                     | 0.56   | 1.9   |
| 5-5-68              | 0.35   | 0.06                                     | 0.51   | 1.7   |
| 5-12-68             | 0.34   | 0.03                                     | 1.6  | 5.3   |
| 5-19-68             | 0.32   | 0.04                                     | 0.53   | 1.8   |
| 5-26-68             | 0.27   | 0.03                                     | 0.20   | 0.67  |
| 6-2-68              | 0.28   | 0.05                                     | 0.97   | 3.2   |
| 6-9-68              | 0.30   | 0.05                                     | 0.16   | 0.53  |
| 6-16-68             | 0.40   | 0.08                                     | 0.40   | 1.3   |
| 6-23-68             | 0.90   | 0.10                                     | 0.15   | 0.50  |
| 6-30-68             | 0.78   | 0.09                                     | 0.11   | 0.37  |
| 7-8-68              | 1.5  | 0.13                                     | 0.15   | 0.50  |
| 7-14-68             | 1.3  | 0.12                                     | 0.12   | 0.40  |
| 7-21-68             | 0.72   | 0.06                                     | 0.06   | 0.20  |
| 7-28-68             | 0.69   | 0.06                                     | 0.05   | 0.17  |
| 8-4-68              | 0.54   | 0.05                                     | 0.04   | 0.13  |
| 8-11-68             | 0.62   | 0.06                                     | 0.04   | 0.13  |
| 8-18-68             | 0.50   | 0.04                                     | 0.03   | 0.10  |
| 8-25-68             | 0.39   | 0.03                                     | 0.02   | 0.07  |
| 9-1-68              | 0.32   | 0.03                                     | 0.03   | 0.10  |
| 9-8-68              | 0.32   | 0.03                                     | 0.04   | 0.13  |
| 9-15-68             | 0.43   | 0.03                                     | 0.21   | 0.70  |
| 9-22-68             | 0.42   | 0.04                                     | 2.1  | 7.0   |
| 9-29-68             | 0.47   | 0.04                                     | 0.14   | 0.50  |
| 10-6-68             | 0.42   |  |  |   |
| 10-13-68            | 0.54   |  |  |   |

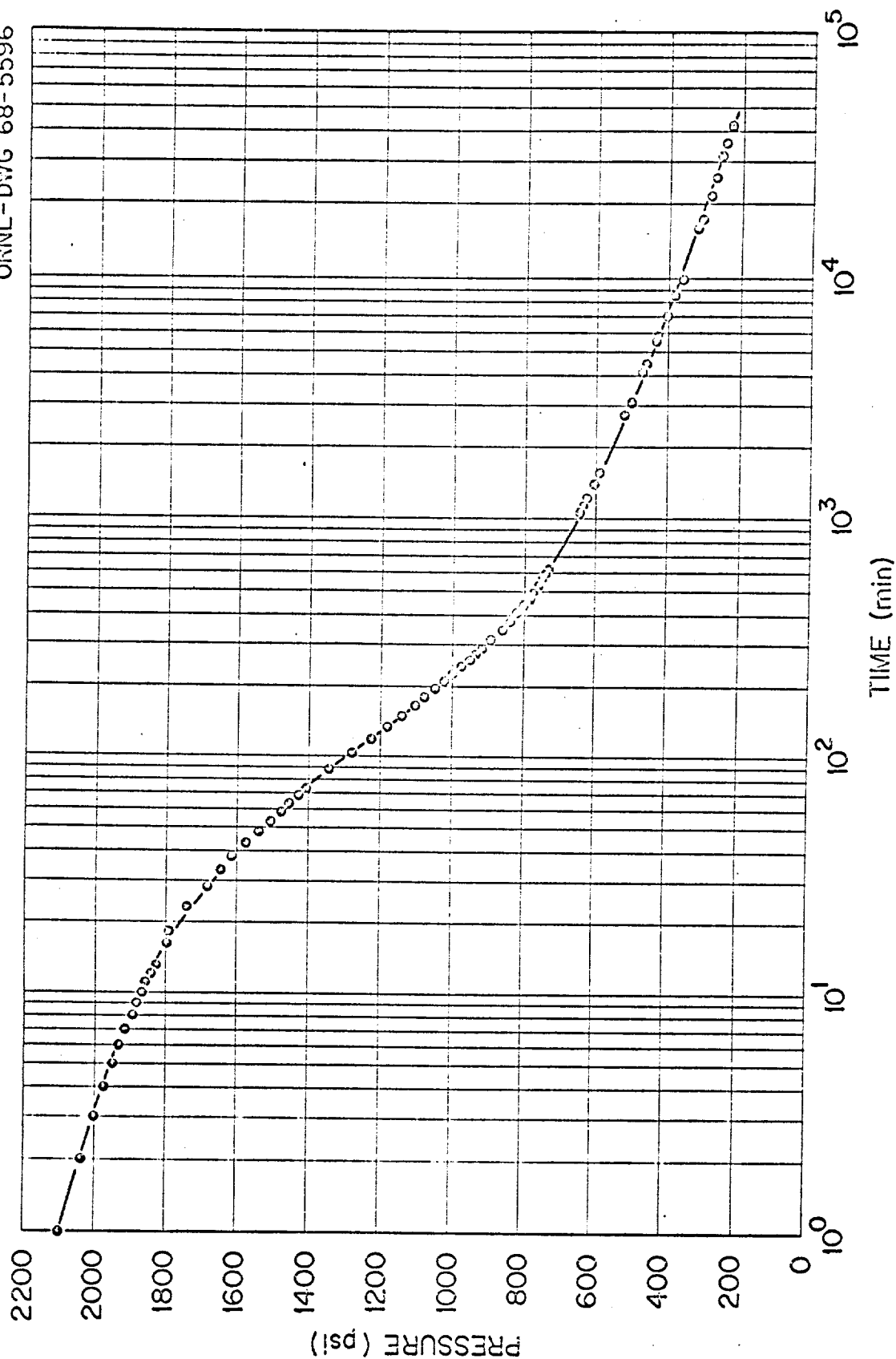
<sup>a</sup>Normally is greater than 90% <sup>90</sup>Sr.<sup>b</sup>Assuming all strontium to be <sup>90</sup>Sr.

Table 4.

Water Sampling at White Oak Lake Dam

| <u>Week Ending</u> | $\frac{^{90}\text{Sr}}{(\text{dis/min/ml})}$ | <u>Week Ending</u> | $\frac{^{90}\text{Sr}}{(\text{dis/min/ml})}$ |
|--------------------|--|--------------------|--|
| May 12             | 0.77   | Aug. 5             | 1.2  |
| May 19             | 0.72   | Aug. 12            | 1.38   |
| May 26             | 0.59   | Aug. 18            | 1.1  |
| June 2             | 0.62   | Aug. 25            | 0.86   |
| June 9             | 0.67   | Sept. 1            | 0.70   |
| June 16            | 0.88   | Sept. 8            | 0.71   |
| June 23            | 1.99   | Sept. 15           | 0.96   |
| June 30            | 1.74   | Sept. 22           | 0.94   |
| July 8             | 3.3  | Sept. 29           | 1.1  |
| July 14            | 3.7  | Oct. 6             | 0.95   |
| July 21            | 1.6  | Oct. 13            | 1.2  |
| July 28            | 1.5  |                    |  |

Figure 1



Injection ILW-4B, April 1968; Pressure as a Function of Time in min.

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